

RAPTOR ENERGETICS: A REVIEW

by

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Ecological energetics, as a discipline, has grown rapidly in recent years. In the broadest sense, it is the study of energy transfers within an ecosystem; however, most research involves only the determination of energy requirements for various categories of activity for a range of organisms. Much interest has focused on thermoregulatory adaptations by endotherms to desert and arctic environments (Schmidt-Nielsen 1964, Scholander 1955, Scholander et al. 1950 a, b, and c, and Irving et al. 1955).

This review is not intended to deal with the enormous volume of literature on endotherm or even avian energetics. I will confine the discussion to work which has examined energy transfers involving raptorial species (orders Falconiformes and Strigiformes). These are heterogeneous orders of birds with regard to size, behavior, and habitat, making them interesting but difficult groups to work with both in the laboratory and in the field.

The ease with which such standard data as body temperature, oxygen consumption, carbon dioxide production, food consumption, and excreta production can be collected varies considerably with the species. Thus technical problems account, in part, for the deficiency in our understanding of raptor energetics which will become apparent in this review. Since 1927 only 28 species have been studied by 20 workers with sample sizes ranging from 1 to 29 (table 1). Ignoring the largest study, the upper limit drops to 10. These facts point to a serious problem with the data base: small sample sizes. Most studies consider only minimum energy requirements (under quite variable conditions) and, sometimes, metabolic rate responses to several environmental temperatures. Very few studies have focused on specific ecological adaptations or the energetic costs associated with factors such as flight, growth, incubation, or molt.

Review of Methods Employed

In his monograph on ecological energetics, Gessaman (1974) provides an extensive and complete review of methods employed in this discipline. These methods will be mentioned only briefly here.

Food Consumption. By measuring the amount of food consumed and excreta produced, the energy metabolized by an animal can be estimated if constant weight of the animal over the period of measurement is assumed. Such data also permit the calculation of digestive efficiency which is of ecological interest.

Respiratory Gas Exchange. The rate at which an animal uses oxygen or produces carbon dioxide is an indirect estimate of metabolic rate. Given both these measurements simultaneously, we may calculate the respiratory quotient which is an indication of the proportion of protein, carbohydrate, and fat that is being metabolized, provided uric acid content of excreta is also known. Such information permits a more

accurate estimate of heat production (metabolic rate) than does oxygen consumption or carbon dioxide production alone.

Review of Results

This review is divided into three parts. The first deals with the relationship between body weight and metabolic rate. The second discusses work dealing with the energy cost of productive work (e.g., flight). The third reviews studies which examined responses to varying ambient temperatures and other environmental variables.

Body Size and Metabolic Rate. The relationship between body size and metabolic rate for endotherms has received considerable attention beginning with the work of Brody (1942), Klieber (1961), and Scholander et al. (1950 a, b, and c). This work, for birds, has been reviewed thoroughly in *Avian Energetics* by Calder (1974).

Considerable discussion has surrounded the question of how best to describe (mathematically) the relationship which take the general form: $M = aW^b$, where M is metabolic rate, W is body mass, a is constant, and the exponent b describes the effect of size (Lasiewski and Dawson 1967, 1969; Zar 1968, 1970). The pertinent formulas with respect to raptors were presented by Zar (1968).

The regression formula for standard metabolic rate on body weight was determined empirically based on five species of falconiforms ranging in weight from 0.108 kg to 10.320 kg. The equivalent equation for strigiforms was based on 6 species over a weight range from 0.0377 kg to 1.450 kg. Collins et al. (in prep.) have calculated a revised equation with the addition of new data.

More data will undoubtedly improve the accuracy of these regression equations although the interesting problem will be to uncover the causes of significant inter- and intraspecific deviations from the regression line.

Energy Costs of Productive Work. With respect to the energetic cost of productive work, nothing has been published except for the works of Tucker (1970, 1971, and 1973) and Pennycuik (1968) on the cost of flight. Pennycuik's work is primarily theoretical but includes some observations on African vultures. The empirical work of Tucker was carried out on nonraptorial species.

Tucker (1974:306) presents an approximation formula: $P_i = (6.43 \times 10^{-3} h + 94.15) m^{0.974}$ which may be used to calculate the power requirements of flight given a number of assumptions concerning the bird's mass, altitude of flight, airspeed, wind conditions, wingspan, and basal metabolic rate. In this formula h = altitude, m = mass (of bird), P_i = power output (watts). For a complete discussion of the effect of these factors see Tucker's review in Paynter (1974).

I have included this material relating to nonraptorial species because the equation developed by Tucker and Pennycuik can be applied with reasonable confidence in the development of energetic models from field data. Bartholomew (in Paynter 1974:329) sums it up nicely, "Knowing these things, any one of us . . . can, by using the tertiary formulae, get values as accurate or more accurate than one could obtain by direct physiological measurement."

Response to Climatological Factors. Cold Environments. Data for metabolic rates at controlled temperatures outside the thermoneutral zone are available for only five species (Ligon 1969, Coulombe 1970, Gessaman 1972). These data, all for owls, are summarized in figure 1.

The values given for the lower critical temperature are of particular ecological interest. They are commonly accepted as an indication of an animal's tolerance of cold and reflect the insulative quality of the plumage (Scholander et al. 1950 c). This rela-

tionship is readily observed in figure 1, which shows a much lower critical temperature and a shallower slope for the Snowy Owl (*Nyctea scandiaca*) than for the other four species. There are no comparable data for falconiforms.

Hot Environments. At ambient temperatures approaching or exceeding normal body temperature, an animal is faced with the problem of dissipating excess heat and/or reducing the absorption of heat from the environment. This can be accomplished both behaviorally and physiologically.

Panting is commonly used by raptors under heat stress. It has the effect of moving relatively large quantities of air over the moist respiratory surfaces thereby removing water vapor. Since water has a high heat of vaporization, it is an effective mechanism for heat dissipation, providing the animal can efficiently replace the lost water and maintain proper blood gas concentrations. Panting also adds to the heat burden because of the associated muscular activity.

Ligon (1969) and Coulombe (1970) have reported respiratory water loss (RWL) for three species of owls (*Athene cunicularia*, *Otus trichopsis*, and *Micrathene whitneyi*). These data show a rapid and substantial rise in RWL commencing at an ambient temperature approximately equal to body temperature. The sharp jump in RWL was associated with the onset of gular fluttering in owls (a mechanism unavailable to the falconiforms). Here again no data on RWL are available for the falconiforms.

Countercurrent vascularization in appendages has been demonstrated for a variety of endotherms (e.g., Irving and Krog 1955, Scholander et al. 1950). Bartholomew and Cade (1957) have reported the only study of this mechanism in raptors. They demonstrated in American Kestrels (*Falco sparverius*) a rise in tarsal temperature associated with increasing ambient temperature, thereby reducing the gradients between tarsal and core temperature, and ambient and tarsal temperature. As ambient temperature approached normal body temperature, so also did tarsal temperature, and this corresponded to a rise in body temperature. Presumably, the rise in tarsal temperature was caused by increased blood flow due to vasodilation (Bartholomew and Cade 1957). A similar response has been demonstrated in several large falcons (Mosher and White 1978).

Sun Bathing. Several avian studies have pointed out the value of sunbathing as a supplement to endogenous heat production (Hamilton and Heppner 1967, Lustick 1969). Other studies have discussed the relationship of a spread-wing posture observed in Ciconiidae (Kahl 1971) and raptors (Cade 1973). While sunbathing apparently provides a supplementary source of heat under some conditions, the spread-wing posture of some raptors appears not to be correlated with control of body temperature (Cade 1973).

Circadian Rhythms in Metabolic Rate. Daily cycles in metabolic rate and body temperature have been recorded for raptors associated with their nocturnal or diurnal habits (Bartholomew and Cade 1957, Graber 1962, Coulombe 1970, Gatehouse and Markham 1970).

The most striking of these studies compared two species of owls with a small falcon (Gatehouse and Markham 1970). The owls had higher nighttime standard metabolic rates (SMR), and the falcon had a higher daytime SMR. Such variation in SMR has not always been considered in studies which report this parameter.

Other Factors Affecting Metabolic Rate. There may be sexual differences in metabolic rate unrelated to differences in body size. Although female Broad-winged Hawks (*Buteo platypterus*) are about 15 percent heavier than males, they have the same weight specific metabolic rate (Mosher and Matray 1974).

Wind is a significant factor in an animal's thermal environment and can have a

considerable impact on the rate of heat loss. Gessaman (1974) is the only worker to report the effects of wind velocity on metabolic rate for a raptor. He found oxygen consumption of Snowy Owls to be a linear function of the square root of airspeed at -20° and -30° C.

Plumage color, unrelated to absorption of radiant energy, may also be related to metabolic rate. Red phase Screech Owls have higher metabolic rates at low ambient temperatures than do gray phase birds (Mosher and Henny 1976). This difference may be due to differences in plumage conductance.

Future Research Directions

This review has been undertaken for the purpose of pointing out gaps in our knowledge of raptor energetics and to encourage research designed to close these gaps.

Basic data are needed in the following areas: (1) energy cost for productive work, especially molt, incubation, growth, and flight; (2) metabolic response to wind and humidity; (3) seasonal metabolic acclimation; (4) energetic efficiencies—metabolized energy/gross energy intake and efficiency of prey capture, i.e., energy value of captured prey/energy cost of hunting; and (5) sexual differences, unrelated to body weight, in metabolic responses.

Besides these basic data, there are several other problems of broader ecological interest. The thermal environment of the nest is crucial to the young and can affect adults by requiring a greater investment of energy in the form of brooding or shading behavior. Direction of exposure of cliff nests is one factor controlling their thermal environment (Mosher and White 1976). A detailed study including nest temperature, radiation regimen, reflectivity of nest background, and nest success would be significant. How the desert-nesting Ferruginous Hawk (*Buteo regalis*) is adapted to the extremes of temperature it faces would be an equally interesting problem. The solution is likely to be both behavioral and physiological. For example, there may be a relationship between respiratory water loss and the relatively large gapes of the Ferruginous Hawk (Niel Woffinden pers. comm).

Differences in plumage coloration may be correlated with differences in thermal conductances (Mosher and Henny 1976). In addition, there may be regional metabolic adaptations to environmental variation within species as reflected by plumage variation (Blem 1974). Study of plumage thermal conductance is a reasonable starting point.

The ecological importance of predators in community function is generally accepted. A knowledge of their energy requirements and the avenues and efficiencies of energy utilization is equally important.

Bibliography of Raptor Energetics (* indicates papers cited in text)

- Aschoff, J., and H. Pohl. 1970. Rhythmic variations in energy metabolism. *Feder. Proc.* 29:1541-1552.
- *Bartholomew, G. A., and T. J. Cade. 1957. The body temperature of the American Kestrel, *Falco sparverius*. *Wilson Bull.* 69:149-154.
- *Benedict, F. G., and E. L. Fox. 1927. The gaseous metabolism of large wild birds under aviary life. *Proc. Amer. Phil. Soc.* 66:511.
- *Blem, C. R. 1974. Geographic variation of thermal conductance in the House Sparrow *Passer Domesticus*. *Comp. Biochem. Physiol.* 47A:101-108.
- Bond, R. M. 1942. Development of young Goshawks. *Wilson Bull.* 54:81-88.

- *Brody, R. M. 1942. *Bioenergetics of Growth*. Reinhold, New York. 1023 pp.
- Brown, L. H., and A. Watson. 1964. The Golden Eagle in relation to its food supply. *Ibis* 106:78-100.
- *Cade, T. J. 1973. Sun-bathing as a thermoregulatory aid in birds. *Condor* 75:106-108.
- *Calder, W. A., III. 1974. Consequences of body size for avian energetics. In: *Avian Energetics*. R. A. Paynter, Jr., ed. *Publ. Nuttall Ornithol. Club*. No. 15, Cambridge, Mass.
- Calder, W. A., and J. R. King. 1972. Body weight and the energetics of temperature regulation: a reexamination. *J. Exp. Biol.* 56:775-780.
- Collins, C. T. 1963. Notes on the feeding behavior, metabolism, and weight of the Saw-whet Owl. *Condor* 65:528-530.
- *Coulombe, H. N. 1970. Physiological and physical aspects of temperature regulation in the Burrowing Owl *Speotyto cunicularia*. *Comp. Biochem.* 35:307-337.
- Earhart, C. M., and N. K. Johnson. 1970. Size dimorphism and food habits of North American owls. *Condor* 72:251-264.
- El-Wailly, A. S. 1966. Energy requirements for egg-laying and incubation in the Zebra Finch, *Taeniopygia castanotis*. *Condor* 68:582-594.
- *Fevold, J. R., and J. J. Craighead. 1958. Food requirements of the Golden Eagle. *Auk* 75:312-317.
- *Fowler, F. H. 1931. Studies of food and growth of the Prairie Falcon. *Condor* 33:193-201.
- *Gatehouse, S. N., and B. J. Markham. 1970. Respiratory metabolism of three species of raptors. *Auk* 87:738-741.
- *Gessaman, J. A. 1972. Bioenergetics of the Snowy Owl (*Nyctea scandiaca*). *Arctic and Alpine Res.* 4:223-238.
- *Gessaman, J. A. 1974. *Ecological energetics of homeotherms*. Utah State University Press, Logan, Utah.
- Gessaman, J. A., G. E. Folk, Jr., and M. C. Brewer. 1965. Telemetry of heart rate from eight avian species. *Amer. Zool.* 5:696.
- *Giaja, J., and B. Males. 1928. Sur la valeur du métabolisme de base de quelques animaux en fonction de leur surface. *Ann. Physiol. Physiochim. Biol.* 4:875-904.
- *Graber, R. R. 1962. Food and oxygen consumption in three species of owls (Strigidae). *Condor* 64:473-487.
- *Hamilton, W. J., III, and F. H. Heppner. 1967. Radiant solar energy and the function of black homeotherm pigmentation: an hypothesis. *Science* 155:196-197.
- Hatch, D. E. 1970. Energy conserving and heat dissipating mechanisms of the Turkey Vulture. *Auk* 84:111-124.
- *Herzog, D. 1930. Untersuchungen über der Grundumsatz der vogel, *Wiss. Arch. Landwirtschaft. Abt. B Arch. Tierernähr. U. Tierzucht* 3:610-626.
- Hill, N. P. 1944. Sexual dimorphism in the Falconiformes. *Auk* 61:228-234.
- Howell, T. R. 1964. Notes on incubation and nestling temperatures and behavior of captive owls. *Wilson Bull.* 76:28-36.
- Irving, L. 1972. *Arctic life of birds and mammals*. Springer-Verlag, New York.
- *Irving, L., and H. Krog. 1955. Temperature of skin in the Arctic as a regulator of heat. *J. Appl. Physiol.* 7:355-364.
- *Irving, L., H. Krog, and M. Monson. 1955. The metabolism of some Alaskan animals in winter and summer. *Physiol. Zool.* 28:173-185.
- *Johnson, W. D. 1974. The bioenergetics of the Barn Owl, *Tyto alba* M.S. Thesis. California State University, Long Beach. 55 pp.

- *Johnson, W. D., and C. J. Collins. 1975. Notes on the metabolism of the Cuckoo Owllet and Hawk Owl. *Bull. South. Calif. Acad. Sci.* 74(1):44-45.
- *Kahl, M. P. 1971. Spread-wing postures and their possible functions in the Ciconiidae. *Auk* 88:715-722.
- Kendeigh, S. C. 1969. Energy response of birds to their thermal environments. *Wilson Bull.* 81:441-449.
- Kendeigh, S. C. 1970. Energy requirements for existence in relation to size of bird. *Condor* 72:60-65.
- Kendeigh, S. C. 1972. Energy control of size limits in birds. *Amer. Natur.* 106:947.
- *Kleiber, M. 1961. *The fire of life: an introduction to animal energetics.* John Wiley and Sons, New York.
- *Lasiewski, R. C., and L. R. Dawson. 1967. A reexamination of the relation between standard metabolic rate and body weight in birds. *Condor* 69:13-23.
- *Lasiewski, R. C., and L. R. Dawson. 1969. Calculation and miscalculation of the equation relating avian standard metabolism to body weight. *Condor* 71:335-336.
- LeFebvre, E. A. 1964. The use of D_2O^{18} for measuring energy metabolism in *Columba livia* at rest and in flight. *Auk* 81:403-416.
- *Ligon, J. D. 1969. Some aspects of temperature relations in small owls. *Auk* 86:458-472.
- *Lustick, S. 1969. Bird energetics: effects of artificial radiation. *Science* 163:387-390.
- *Mosher, J. A., and C. Henny. 1976. Thermal adaptiveness of plumage color in screech owls. *Auk* 93:614-619.
- *Mosher, J. A., and P. F. Matray. 1974. Size dimorphism: a factor in energy savings for Broad-winged Hawks. *Auk* 91:325-341.
- *Mosher, J. A., and C. M. White. 1976. Directional exposure of Golden Eagle nests. *Can. Field-Natur.* 90:356-359.
- *Ondorff, R. R. 1971. Morphological aspects of growth in three species of hawks. Ph.D. dissertation. Colorado State University, Ft. Collins.
- Parrott, B. C. 1970. Aerodynamics of gliding flight of a Black Vulture *Coragyps atratus*. *J. Exp. Biol.* 53:363-374.
- *Paynter, R. A., Jr. 1974. Avian Energetics. *Publ. Nuttall Ornithol. Club.* No. 15, Cambridge, Mass. 334 pp.
- *Pennycuick, C. J. 1968. Power requirements of horizontal flight in the pigeon *Columba livia*. *J. Exp. Biol.* 49:527-555.
- Pennycuick, C. J. 1972. Soaring behavior and performance of some East African birds observed from a motor-glider. *Ibis* 114:178-218.
- Raveling, D. G., and E. A. LeFebvre. 1967. Energy metabolism and theoretical flight range of birds. *Bird-Banding* 38:97-113.
- Reynolds, R. 1972. Sexual dimorphism in accipiter hawks: a new hypothesis. *Condor* 74:191-197.
- Ricklefs, R. E. 1968. Patterns of growth in birds. *Ibis* 110:419-451.
- Scharf, D., and E. Balfour. 1971. Growth and development of nestling Hen Harriers. *Ibis* 3:113.
- *Schmidt-Nielsen, K. 1964. *Desert animals: Physiological problem of heat and water.* Clarendon Press, Oxford.
- *Scholander, P. F. 1955. Evolution of climatic adaptation in homeotherms. *Evolution* 9:15-26.
- *Scholander, P. F., R. Hock, V. Walters, F. Johnson, and L. Irving. 1950a. Heat regulation in some Arctic and tropical mammals and birds. *Biol. Bull.* 99:237-258.

- *Scholander, P. F., V. Walters, R. Hock, and L. Irving. 1950b. Body insulation of some Arctic and tropical mammals and birds. *Biol. Bull.* 99:225-236.
- *Scholander, P. F., R. Hock, V. Walters, and L. Irving. 1950c. Adaptation to cold in Arctic and tropical mammals and birds in relation to body temperature, insulation, and basal metabolic rate. *Biol. Bull.* 99:259-271.
- Storer, R. W. 1966. Sexual dimorphism and food habits in three North American accipiters. *Auk* 83:423-436.
- Sumner, E. L., Jr. 1929. Notes on the growth and behavior of young Golden Eagles. *Auk* 46:161-169.
- Sumner, E. L., Jr. 1929. Comparative studies on the growth of young raptors. *Condor* 31:85-111.
- Sumner, E. L., Jr. 1933. The growth of some young raptorial birds. *Univ. Calif. Publ. Zool.* 40:277-307.
- Tucker, V. 1969. The energetics of bird flight. *Sci. Amer.* 220 (5):71-76.
- *Tucker, V. 1970. Energetic cost of locomotion in animals. *Cong. Biochem. Physiol.* 34:841-846.
- *Tucker, V. 1971. Flight energetics in birds. *Amer. Zool.* 11:115-124.
- *Tucker, V. 1973. Bird metabolism during flight: evaluation of a theory. *J. Exp. Physiol.* 58:689-709.
- *Tucker, V. 1974. Energetics of natural flight. In R. A. Paynter, ed. *Avian energetics. Publ. Nuttall Ornithol. Club.* No. 15, Cambridge, Mass.
- Van Camp, L. F., and C. J. Henny. 1975. The Screech Owl: its life history and population ecology in Northern Ohio. *North Amer. Fauna.* No. 71, 65 pp.
- *Zar, J. H. 1968. Standard metabolism comparisons between orders of birds. *Condor* 70:278.
- *Zar, J. H. 1970. On the fitting of equations relating avian standard metabolism to body weight. *Condor* 72:247.

A CHEAP METHOD OF DIVIDING LARGE PENS FOR BREEDING RAPTORS

by
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If you wish to separate a pair of birds over winter or to divide a large pen into smaller ones, we found that inexpensive canvas panels were excellent for this purpose.

The panels can be cut to size and nailed to the ceiling, floor, and walls with narrow strips of plywood and small nails. Small, weighted flaps covered the feed holes, and two 20-inch-long zippers were sewn about 2 feet apart as a door for each pen. These doors were used for changing bath water and entering pens.

These panels are inexpensive and fast to assemble and take down. They can be reused numerous times and are easy to wash and store when not in use. They can be left up as permanent partitions or put up and removed as required.

We have used these panels to winter female Peregrines and Merlins with very satisfactory results.

TABLE 1
SUMMARY OF RAPTOR ENERGETICS STUDIES

Species	N	Methods	Factors Studied										Reference
			T	W	F	M	I	BS	C	S	G	Other	
<i>Buteo jamaicensis</i>	5	Food Con.										*	Olendorff 1971
<i>Buteo swainsoni</i>	4	"										*	"
<i>Buteo regalis</i>	5	"										*	"
<i>Buteo platypterus</i>	7	Food Bal.							*				Sex, EE Mosher & Matray 1974
<i>Accipiter gentilis</i>	1	Food Con.											EE Fevold & Craighead 1958
<i>Aquila chrysaetos</i>	3	Food Con.											EE "
<i>Falco sparverius</i>	3	O ₂ /CO ₂										*	Gatehouse & Markham 1970
"	10	Temp.	*										Bartholomew & Cade 1957
"	—	O ₂ & D ₂ O ¹⁸	*										HR Gessaman unpubl.
<i>Accipiter nisus</i>													SMR Giaja & Males 1928
<i>Falco mexicanus</i>	2	Lin. M.										*	Fowler 1931
<i>Falco peregrinus</i>	8	Temp.	*										Mosher & White unpubl.

Table 1 cont.

Species	N	Methods	Factors Studied									Reference		
			T	W	F	M	I	BS	C	S	G		Other	
<i>Geranoaetus melanoleucus</i>												SMR	Benedict & Fox 1927	
<i>Gypaetus barbatus</i>												SMR	"	
<i>Vultur gryphus</i>												SMR	"	
<i>Aegolius acadicus</i>	1	O ₂ /CO ₂								*			Gatehouse & Markham 1970	
"	2	O ₂ & Temp.	*							*		RWL	Ligon 1969	
"	2	Food Bal. & O ₂								*	*	*	EE	Graber 1962
"			*					*				SMR	Collins 1963	
<i>Otus asio</i>	1	O ₂ /CO ₂								*			Gatehouse & Markham 1970	
<i>Otus asio</i>	2	O ₂ & Temp.	*							*		RWL	Ligon 1969	
<i>Otus tricopsis</i>	3	"	*							*		"	"	
<i>Glaucidium gnoma</i>	3	O ₂ & Temp.	*							*		RWL	Ligon 1969	
<i>Micrathene whitneyi</i>	3	"	*							*		"	"	
<i>Asio flammeus</i>	1	Food Bal. & O ₂								*	*	*	EE	Graber 1962
<i>Asio otus</i>	1	"								*	*	*	EE	"
<i>Athene cucularia</i>	29	O ₂ & Temp.	*							*			RWL & SR	Coulombe 1970

Table 1 cont.

Species	N	Methods	Factors Studied										Reference	
			T	W	F	M	I	BS	C	S	G	Other		
<i>Otus flammeolus</i>	2	O ₂											RWL	Mosher & Woffinden unpubl.
<i>Nyctea scandiaca</i>	4	O ₂ /CO ₂ & Food Bal.	*	*									Insul.	Gessaman 1972
<i>Bubo virginianus</i>													SMR	Benedict & Fox 1927
<i>Strix aluco</i>													SMR	Herzog 1930
<i>Tyto alba</i>		O ₂ Food Bal.	*					*					EE, Insul	Johnson 1974
<i>Surnia ulula</i>	1	O ₂	*					*					SMR	Johnson & Collins 1975
<i>Glaucidium cuculoides</i>	1	O ₂	*					*					SMR	"

*Note the following abbreviations: T-temperature, W-wind, F-flight, M-molt, I-incubation, BS-body size, C-circadian rhythms, S-seasonal rhythms, G-growth, SMR-standard metabolic rate, RWL-respiratory water loss, EE-existence energy, SR-surface radiation, Insul.-insulation, HR-heart rate, Food Cons.-food consumption, Food Bal.-food balance calorimetry, Temp.-temperature measurement, Lin M.-linear measurements.

BALLOT FOR ELECTION OF BOARD OF DIRECTORS

The ballot is included as a separate item in this mailing. Please note that ballots are to be returned to the secretary, Dr. Don Johnson. Although the return deadline is given as July 1, ballots will be accepted up to the end of August, owing to the late mailing. Please vote!

NEW EDITOR OF RAPTOR RESEARCH

After several years of faithful service, Dr. Richard Olendorff (aka "Butch") has asked to be relieved of the editorial burden. Dr. Clayton White of the Department of Zoology, Brigham Young University, has agreed to serve as the new editor, effective immediately. On behalf of the board of directors and membership, we extend our sincere appreciation to Butch and our best wishes to Clay for a successful tenure as editor.

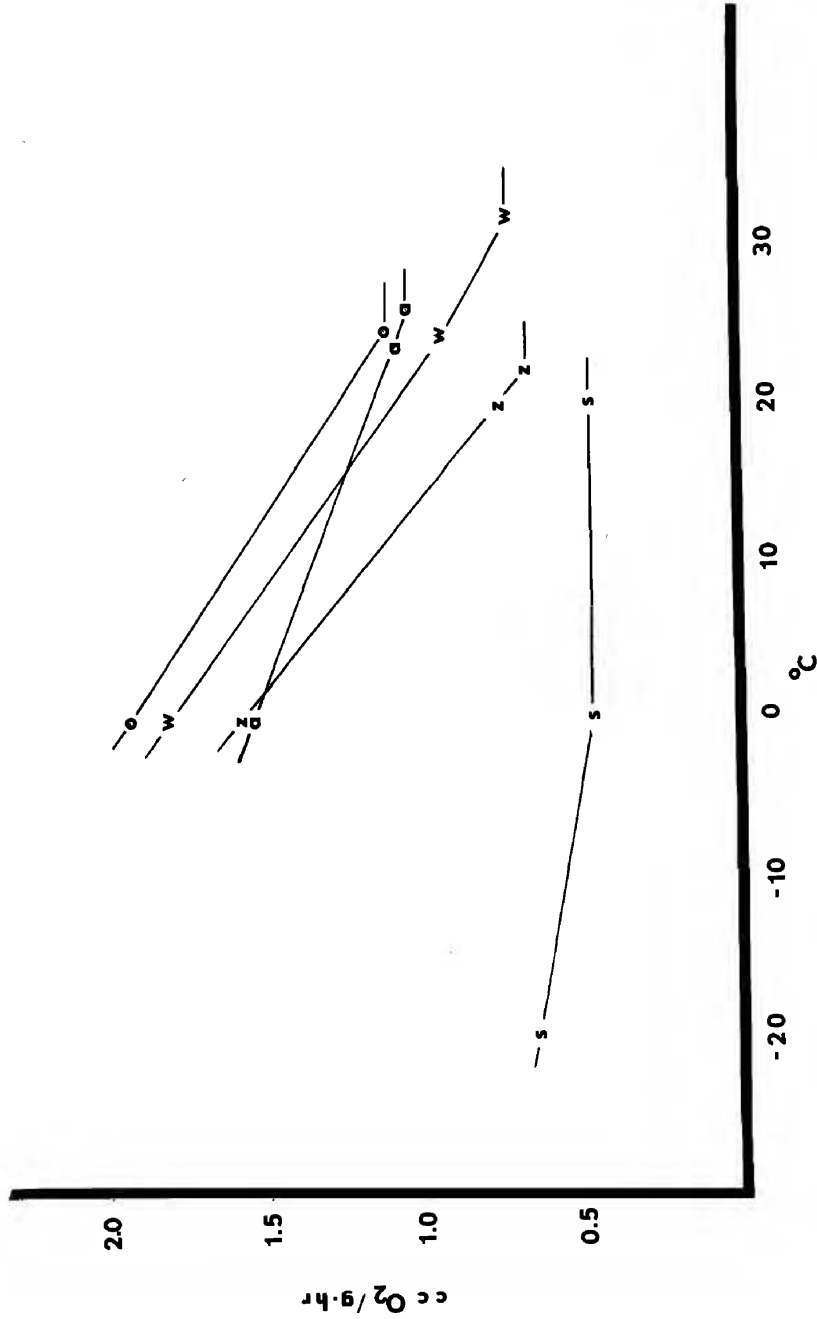


Figure 1. Oxygen consumption response of several owls to decreasing ambient temperatures (Ligon 1969, Gessaman 1972, and Coulombe 1970). The symbols are as follows: o-*Athene cunicularia*, w-*Otus trichopsis*, x-*Otus asio* c., a-*Aegolius acadicus*, and s-*Nyctea scandiaca*.